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In August 1992, an experiment was started in Alaska to measure and characterize auroral-E propagation. A 100 watt transmitter was installed at the Arctic Submarine Laboratory facility at Cape Prince of Wales (67N,168W). A receiver was installed 900 km away at RP Consultants' facilities in Fairbanks (65N,148W). Both sites used simple dipole antennas. The transmitter sent a slow morse "R" on a frequency of 25.545 MHz. Only a very dense patch of ionization, typical of sporadic-E or auroral-E with foEs of greater than 5 MHz, would sustain a skywave signal over this path. During the year long test period, the solar sunspot number declined from 175 to below 100. Over 1400 auroral sporadic mode observations were recorded with durations spanning 1 minute to several hours. A strong diurnal dependence was noted. This paper presents an initial characterization of auroral-E occurrence with respect to time of day, season and magnetic activity. Also some implications are discussed with respect to intensity. Finally, the new data are discussed with respect to the development of a new auroral-E expert system model.

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RESULTS FROM A YEAR-LONG AURORAL-E MEASUREMENT CAMPAIGN

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ABSTRACT

In August 1992, an experiment was started in Alaska to measure and characterize auroral-E propagation. A 100 watt transmitter was installed at the Arctic Submarine Laboratory facility at Cape Prince of Wales (67N,168W). A receiver was installed 900 km away at RP Consultants' facilities in Fairbanks (65N,148W). Both sites used simple dipole antennas. The transmitter sent a slow morse "R" on a frequency of 25.545 MHz. Only a very dense patch of ionization, typical of sporadic-E or auroral-E with foEs of greater than 5 MHz, would sustain a skywave signal over this path. During the year long test period, the solar sunspot number declined from 175 to below 100. Over 1400 auroral sporadic mode observations were recorded with durations spanning 1 minute to several hours. A strong diurnal dependence was noted. This paper presents an initial characterization of auroral-E occurrence with respect to time of day, season and magnetic activity. Also some implications are discussed with respect to intensity. Finally, the new data are discussed with respect to the development of a new auroral-E expert system model.

INTRODUCTION

In 1989, the Disturbance Impact Assessment System (DIAS) was developed to make qualitative assessments of the impact of solar flares on high latitude HF propagation [Rose (1992)]. The system employed new techniques in "expert system" technology to describe some of the vaguer aspects in high latitude disturbance phenomenology. In developing the rulesets for the different high latitude disturbances, it was obvious that there was some confusion regarding the occurrence characteristics of sporadic-E, auroral sporadic-E, and just plain auroral-E. It was very difficult to determine the type of sporadic ionization being described in different studies.

In order to gain better insight on the characteristics of auroral-E so an accurate ruleset for DIAS could be developed, it was decided to conduct a year-long measurement campaign. This report will describe the results of the first year of measurements, present theories on the generation of sporadic ionization at E-region ionospheric heights and finally attempt to correlate the observations to the theories.

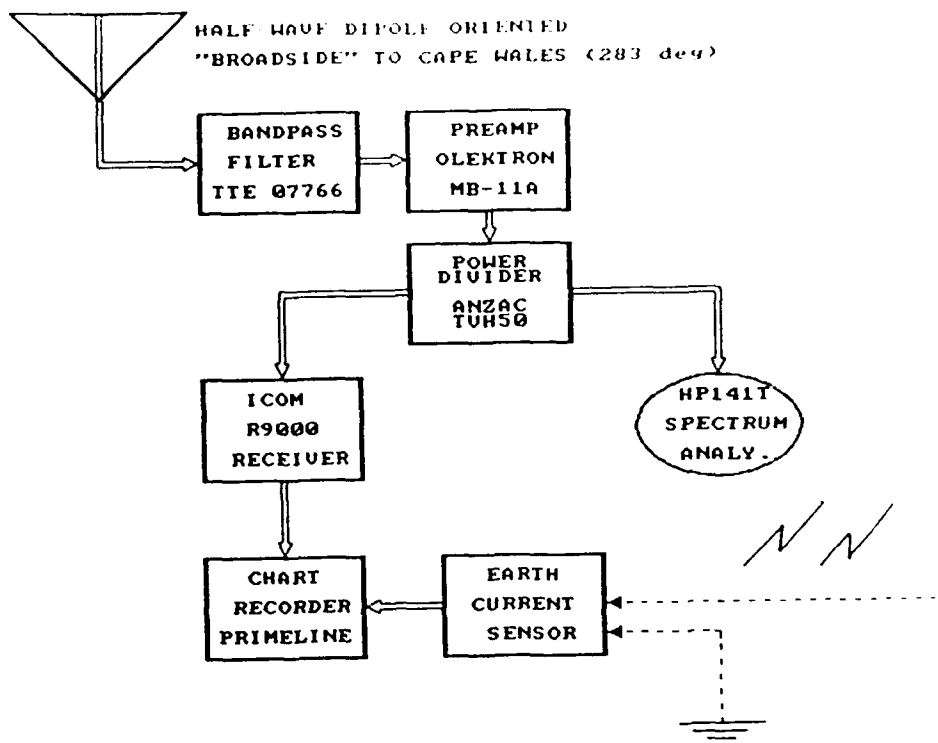
EXPERIMENTAL DESCRIPTION

In July 1991, a 960 km experimental circuit was established in Alaska between the Arctic Submarine Laboratory at Cape Prince of Wales, Alaska (65.6N, 168W) and a facility at RP Consultants in Fairbanks, Alaska (64.8N, 147.8W). In order to sense anomalous or sporadic patches of ionization drifting at E-region height, a frequency of 25.545 Mhz was chosen for a continuously transmitting beacon at Cape Wales. Whenever the E-region critical frequency rose above 5 MHz (very dense at these latitudes) at the E-region midpoint at 64.6N and 107W, the signal could be heard in Fairbanks indicating sporadic ionization was present [Hunsucker (1991)].

A block diagram of the experiment is shown in Figure 1. The transmitter is a Yaesu FT-757 providing 100 watts to a half wave dipole antenna. The signal was a slow morse "R". Transmissions were continuous, 24 hours a day. Except for two periods where high winds broke the antenna, the data collection was continuous between 15 August 1991 and 16 August 1992.

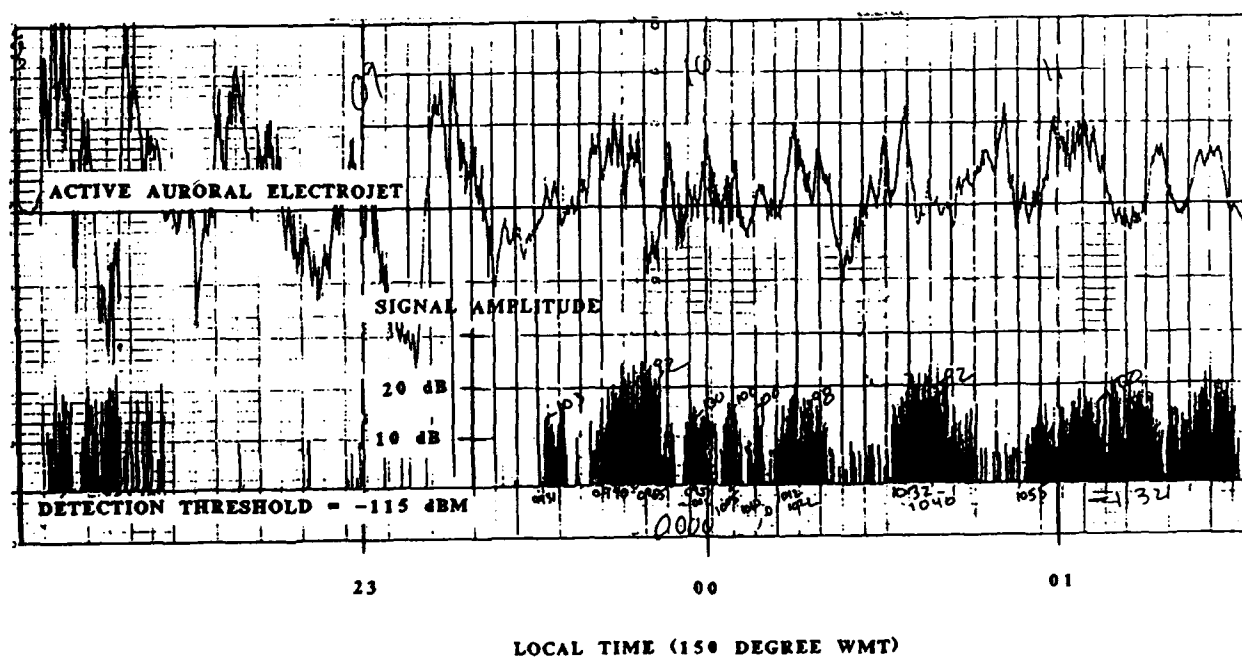
The receiver, an Icom R9000, was located in Fairbanks and continuously monitored the 25.545 MHz signal. The AGC output from the R9000 measured relative signal amplitude and was recorded on a Primeline Chart Recorder as a function of time. Approximately 6 days of monitoring could be recorded on a single pack of chart paper. To supplement the auroral-E information recorded, a Telluric-current sensor, with electronics oriented north-south, was installed to measure the current induced in the ground from the auroral electrojet. This was done in an attempt to correlate variations in the auroral electrojet and the occurrence of auroral-E.

Figure 2, an example of a strip of data recorded in Fairbanks shows what this simple experimental setup produced. The lower trace is relative signal amplitude. The upper trace shows variations in the electrojet as measured by the Telluric-current sensor. In this example there are 14 discrete sporadic ionization events centered around local midnight. As is seen in Figure 3, a magnetic index (Kp) of 3 or greater is required for the equatorward edge of the auroral oval to pass over and south of our experimental HF path. The vast majority of measurements gathered for this report were done during significant magnetic substorms.



AURORAL-E RECEIVER CONFIGURATION

Figure 1



MULTIPLE AURORAL-E EVENTS 23 NOVEMBER 1991, Kp=4, Ap=24

Figure 2

DATA PREPARATION

When the strip chart data were received from the field, a template was created from the calibration strip made at the test site. The purpose of the template is to scale the duration and the relative signal amplitude of the auroral-E event. The magnetic indices, Kp and Ap were annotated on the chart near the event. There are several reasons why this analysis uses simple hand scaling techniques on this data.

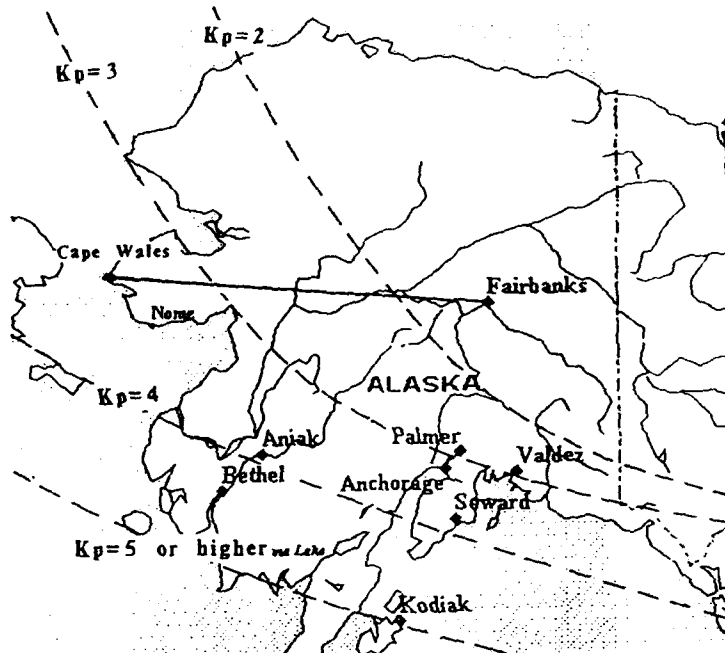
(a) The data are analog. Hand-scaling allows the analysts to "read-between-the-lines" and to identify smaller more obscure events. With experience, the analyst could see auroral-E in the presence of noise and interference.

(b) With periodic re-calibration the signal amplitude accuracy is approximately plus or minus five decibels.

When auroral-E events were observed, the strip chart was annotated with the following parameters:

- (1) Start time of event in UT
- (2) Event Duration
- (3) Signal Amplitude
- (4) Earth Current deviation and magnitude

After scaling and analyzing a given block of data, those portions of the overall chart that contained auroral-E events and calibration data were copied. The last step in the data preparation was to enter the parametric data into a LOTUS 1-2-3 spreadsheet data base.



EQUATORWARD EDGE OF THE AURORAL OVAL
OVER EXPERIMENTAL PATH AS A FUNCTION
OF Kp

Figure 3

PRESENTATION OF THE DATA

Between 15 August 1991 and 15 August 1992, sporadic ionization was observed 1446 times. Because of the nature of the experiment it can be said that the E region critical frequency rose above 5 MHz, allowing the 25.545 MHz signal from Cape Wales to be monitored in Fairbanks. While it is suspected that the majority of observations were auroral-E, either the diffused type occurring prior to local midnight or the discrete type occurring after local midnight, the existence of sporadic-E, like the type observed at mid-latitudes cannot be ruled out. As will be shown subsequently, diurnal characteristics may be useful in separating the two.

TABLE 1. - SEASONAL CHARACTERISTICS

Season	Average Duration	Average Amplitude	# of Events > 60 min.	Longest Duration	Number of Observations
Autumn	9.9 min.	17.4 dB	7	120 min	403
Winter	8.3 min	19.0 dB	2	84 min	383
Spring	8.6 min	18.4 dB	1	65 min	272
Summer	21.0 min	19.2 dB	21	192 min	388

Magnetic and Diurnal Dependencies

Three areas were investigated to determine what dependencies existed in the data. These included (1) occurrences versus local time; (2) occurrences versus magnetic index; and (3) amplitude and duration versus magnetic index.

We will discuss the latter two first. There were no strong correlations between the signal amplitude and duration of observed auroral-E with Kp. Once the Kp reached a value of three the signal amplitude and duration varied irrespective of the Kp. A long duration event was just as likely at a Kp of 3 as at a Kp of 7. It appears that a dependency on Kp is somewhat binary. Once the Kp crosses a threshold of 3, the likelihood of auroral-E occurrence is relatively uniform.

Figures 4, 5, 6 and 7 show the distribution of occurrence as a function of local time of day. These plots show that the probability of occurrence has a high dependency on the local time of day. Figure 4 shows the diurnal variation in the occurrence for Fall 1991. It shows a strong dependency centered on local midnight. During the fall equinox, there is about an equal amount of daylight and night. During daylight hours between 0700 and 1700 local time only a small number of events were observed. Another feature in this plot is a small sub-peak just prior to sunrise at 0600 local time.

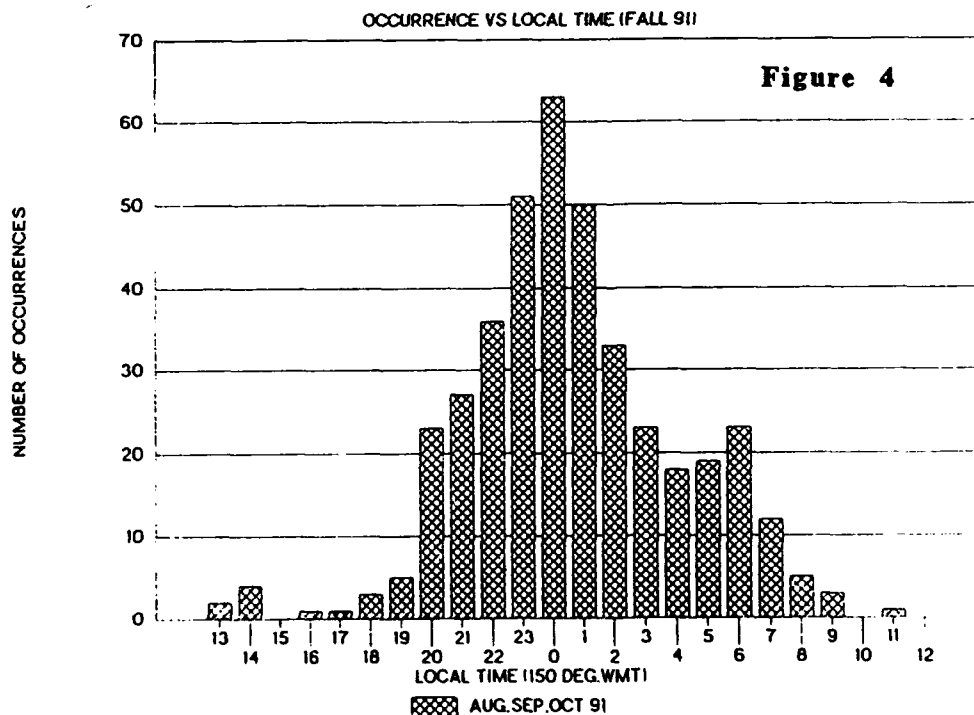
In figure 5, the diurnal characteristics for the Winter solstice is seen. The distribution seems to be shifting to the post-midnight period indicating a strong dominance by the westward electrojet. Still the probability of occurrences is centered on the 2300 to 0100 local time period.

The Spring Equinox, shown in Figure 6, stills shows a peak probability around local midnight with the peak broadening to include the 2200 to 0200 local time period. A secondary peak is also noted just prior to sunrise at 0500 local time.

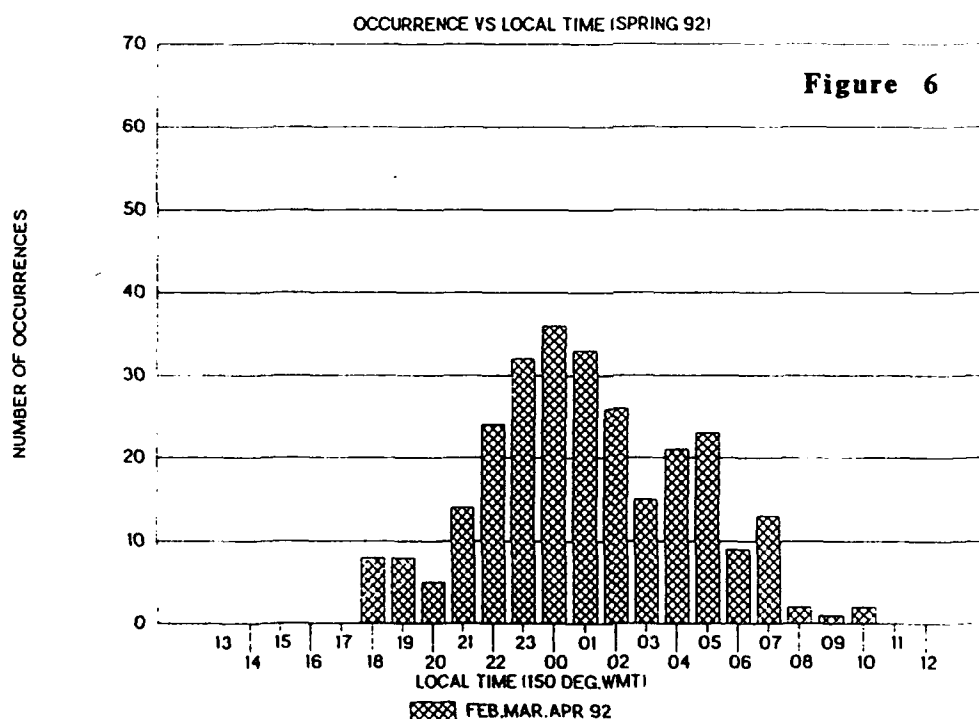
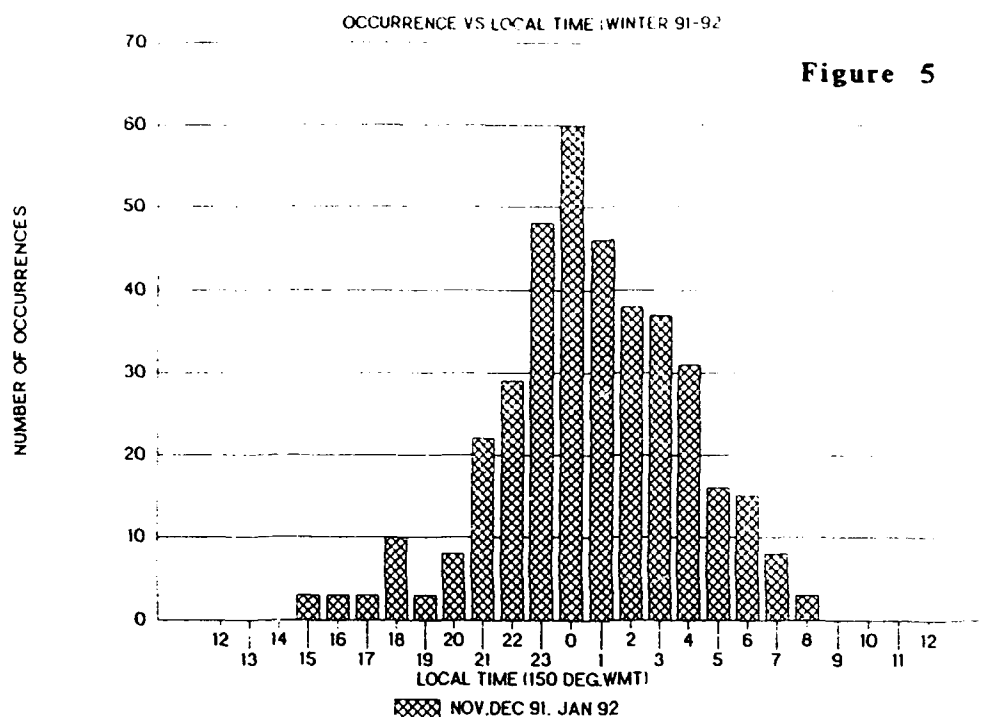
During the Summer solstice, centered in June, the path is in daylight between 0130 and 2300. As is seen in Figure 7, the probability of occurrence has now shifted to between 0100 and 0400 with the distribution curve starting to build as early as 1800 local. Because of the number of events that occurred during the post-sunrise and pre-sunset periods, it is expected that sporadic-E was present a good part of the time. As was mentioned earlier, there is no way to separate the two.

Except for the Summer Solstice, the probability of occurrence of auroral-E is centered around local midnight. Because the preponderance of events occurred after 2200 local time, activity in the westward electrojet caused most of the sporadic propagation observed. During highly disturbed periods, the auroral-E observed would be a combination of E modes created by both diffuse and discrete precipitation.

Figure 8 shows the percentage of days per month where auroral-E occurred. This presentation indicates that the occurrence of auroral-E peaked during the Fall equinox, nulled during the Winter solstice and started to peak again through summer and fall 1992. Through this period of time monthly sunspot numbers declined from values of 150 to lows of 70 as the cycle moved toward solar minimum.



The relative consistency in the maximum signal amplitude indicates that the electron density of each patch also reaches a maximum value. In most cases, either the signal is there or it isn't. There is no consistent "graceful degradation." This is most likely because the peak electron density of the auroral-E region occurs at a narrowly bounded height, between 90 and 120 km. Therefore it would be expected that electron densities being formed by the same ionization source (auroral precipitation) would be about the same.



Early in the experiment, it was attempted to correlate electrojet activity, as evidenced by the earth current meter, to the occurrence of auroral-E. It was observed that the existence of electrojet activity, and not the magnitude of it, correlated to the occurrence of auroral-E. This is consistent with the theory that an increase in the auroral electrojet activity triggers the particle precipitation that causes auroral-E. It should also be mentioned that our earth current meter is installed at the receiving site. It is likely that there would be a better correlation between electrojet variations and received signal variations if the earth current sensor were located under the E-region reflection point at mid-path.

Longer duration events in excess of 60 minutes were seen on occasion. Based on the previous discussion on the formation of auroral-E, a long duration event requires a large sheet of ionization. Figure 9 shows two examples of long duration events, one lasting for 50 minutes and another lasting 80 minutes. Both produced relatively consistent signal amplitudes of 30 dB. Also note the relative lack of activity. This example is almost certainly auroral-E as it occurs with a Kp of 3 in the post midnight sector, many hours prior to sunrise which about 0930 local time.

OCCURRENCE VS LOCAL TIME - SUMMER 92

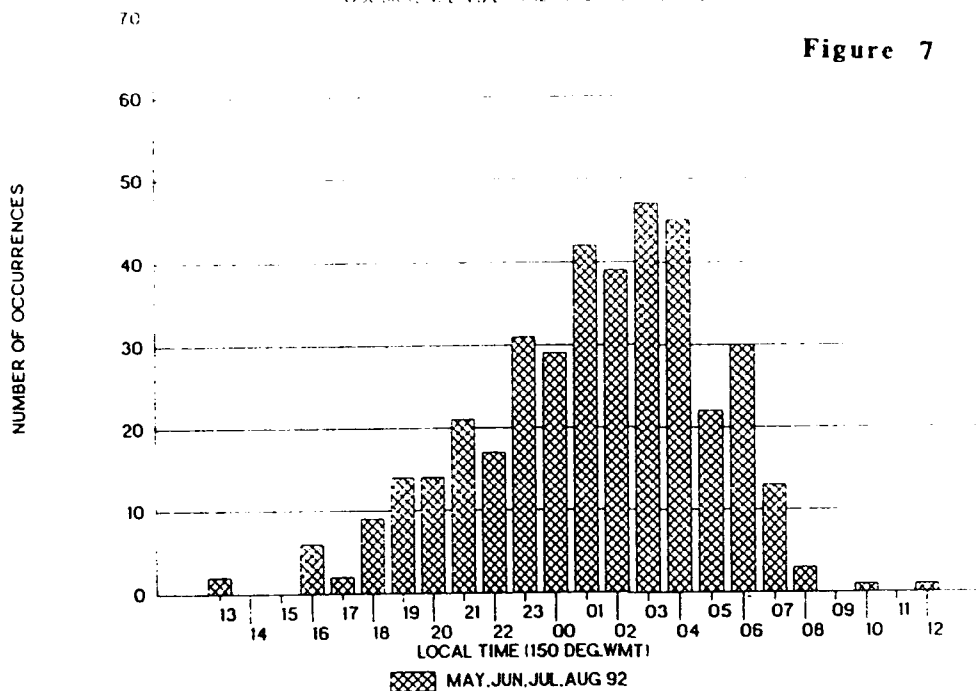


Figure 7

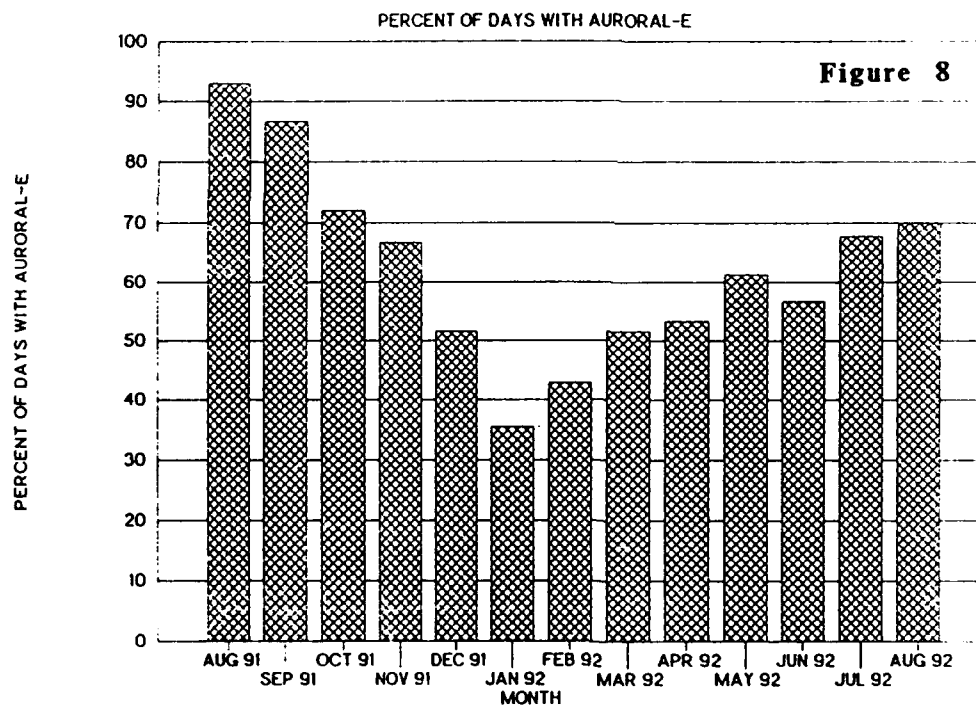


Figure 8

As was mentioned previously, modelers who must typify the auroral ionospheric environment are confronted with three types of E region ionization. These include:

- (1) Sporadic-E (Es)
- (2) Auroral-E - diffuse precipitation
- (3) Auroral-E - discrete precipitation

However it is virtually impossible to separate the three in an oblique sensing experiment such as this one. About the only way is to use diurnal and seasonal characteristics to guess which type is present.

SUMMARY

The objective of this experiment was to sufficiently characterize auroral-E so that an expert system ruleset could be derived for DIAS. This objective was obtained. From the analysis of the data the following observations were made:

1.) Auroral-E is a predominantly night phenomena. Its occurrence is centered around local midnight and several hours after that. In the hours between 2200 and 0300 local time, with the K index sufficiently high to place the auroral oval, and the electrojet over the transmission path, the likelihood of occurrence is 50 %.

2.) Auroral-E is a short lived, intense phenomena. Its onset and demise is abrupt in nature. Out of 1446 observations, 981 (68%) had durations equal to or less than 10 minutes, 234 (16%) had durations between 11 and 20 minutes and 90 (6%) endured between 21 and 30 minutes. 90% of the observations occurred between 1 and 30 minutes. There were 11 events which had durations of greater than 90 minutes. One occurred in the Fall and rest occurred in the spring where 7 events had durations longer than 120 minutes. In the summer months, the night, which is only 2 hours long and the long daylight hours cause auroral-E and sporadic E events to run together.

3.) Auroral-E occurs on 75% of the days each month during the equinoxes, about 68% of the time during the summer and only 36% of the time during the winter.

4.) The ionization patches are sufficiently dense to support oblique propagation in the high HF and LoVHF spectrum. Signal amplitudes were consistently between 20 and 30 dB above the receiver detection threshold of -115 dBm.

5.) There were no significant correlations between Kp and the duration or amplitude of the signals observed. It appears that Kp is useful only in indicating the auroral oval expansion is sufficient to place the electrojet in the vicinity of the area of interest.

6.) Because this sporadic mode is generated from a thin, irregular plasma localized in latitude and longitude, only single hop propagation is likely restricting oblique propagation to less than 1500 Km. However given the right orientation, the likelihood of re-occurrence could be very predictable.

The auroral-E measurement program will be continued for at least another year to observe any changes that might occur at solar minimum approaches. Objectives will be to more closely define the inter-relationships between the auroral electrojet and the onset of auroral-E.

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Figure 9
LONG DURATION AURORAL-E EVENTS

28 NOVEMBER 1991
Ap-12, Kp=3

